



AGRICULTURAL
ENERGY CENTRE



SEALING AND INSULATING

SPECIFIC AREAS OF

BULK TOBACCO KILNS

- final report

Report no. 89-6508 APRIL, 1989

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BY: D. L. Van Hooren, P.Ag.
Agricultural Energy Specialist
Agricultural Energy Centre
Ontario Ministry of Agriculture
and Food
Research Station
Delhi, Ontario.

ABSTRACT

Over a 2 year period, the energy and cost effectiveness of applying a 25 mm thickness of polyurethane foam to the roof, furnace wall, sheet metal partition above the furnace and the outer perimeter of the lower plenum of five bulk tobacco kilns was evaluated. The cost of the polyurethane foam application was \$600 per bulk kiln. As compared to five unmodified bulk kilns at the same site, a natural gas saving of 16% was realized. The simple payback period for the insulation retrofit would be about 7 curing seasons. If the bulk kilns had been fuelled by propane the simple payback period would be about 4 curing seasons.

PROBLEM IDENTIFICATION

The majority of bulk tobacco kilns, manufactured prior to the 1980's, were constructed with fibreboard in their roofs. Today, many tobacco producers with these kilns are experiencing problems with the fibreboard. After many cycles of curing and conditioning tobacco in their kilns, the fibreboard has deteriorated so badly that it is separating from the metal roof and rafters. Figure 1 shows fibreboard that has separated from a kiln roof.

The deterioration of the fibreboard can be attributed to high humidity conditions during the early stages of curing and later during the conditioning process. During the yellowing phase of tobacco curing, when air relative humidity is maintained between 82 and 93%, water vapour travels through the fibreboard and condenses on the underside of the metal roof. The water droplets are then absorbed by the fibreboard increasing its weight. This is repeated again during the conditioning process after curing. Eventually, because of the added weight from the water, the fibreboard sags and separates from the rafters and metal roof of the kiln. In some instances pieces of the fibreboard will even break off and fall on to the tobacco in the top tier of the kiln.

Many serious problems result when fibreboard separates from the roof of a kiln:

- i) the air pattern in the upper plenum is changed;
- ii) air circulating in the upper plenum cools as it passes over exposed areas of the metal roof;
- iii) and humidity levels are difficult to maintain since air escapes where the metal roofing sheets overlap.

These problems result in inefficient curing and poor control over curing and conditioning processes which could even lead to poor cured tobacco quality.

As well, many of the kilns constructed with fibreboard in the roofs only have insulation in the walls of the curing compartment. There is no

The mention of manufacturer's trade names is for the purpose of specific product description and does not indicate endorsement or criticism of that product or products not mentioned by the author or the Ontario Ministry of Agriculture and Food.

insulation in the following areas:

- i) steel walls of the lower plenum;
- ii) wood wall separating the curing compartment from the furnace unit;
- iii) and sheet metal partition above the furnace unit which separates the upper plenum of the curing compartment from the furnace unit.

Insulating these areas of the kiln would increase control over curing and conditioning air which could result in improved tobacco quality. In addition, energy requirements would be reduced.

A project was initiated in 1987 to determine the effects of removing fibreboard from kiln roofs and applying polyurethane foam in its place. As well, areas of kilns that were not insulated when manufactured were retrofitted with polyurethane foam.

OBJECTIVES

The objectives of the project were to determine if sealing and insulating different areas of tobacco kilns would affect the following:

- 1) energy and cost requirements to cure and condition tobacco;
- 2) control over curing and conditioning the tobacco;
- 3) cured tobacco quality.

METHOD

Project Site

A demonstration project was conducted at the farm of John Tamsu, R. R. # 2, Courtland. The farm is equipped with ten "Powell" bulk kilns that were manufactured in 1977 and 1978. Each kiln is equipped with 150 racks; a 295 megajoule per hour burner fuelled by natural gas; and a centrifugal blower powered by a 3.7 kW motor.

The construction of each kiln is similar: roof - 45 x 90 mm wood rafters, 20 mm thick fibreboard (RSI 0.36) and metal roofing; outside walls - 15 mm thick plywood, 75 mm thick fibreglass (RSI 1.55), 45 x 90 mm studs and metal siding; and wall separating furnace unit from curing compartment - 15 mm thick plywood and 45 x 90 mm studs.

Sealant and Insulation

It was decided that polyurethane foam would be the most appropriate material for this type of application. Polyurethane foam has many positive attributes: adheres to most surfaces; forms a monolithic layer which prevents air infiltration and exfiltration (critical for this application); low permeability to water penetration; and a 0.43 RSI per cm of thickness.

Polyurethane Foam Application

The ten bulk kilns on the Tamsu farm are situated in a single row. During harvest, the bulk kilns are loaded consecutively starting at one end of the row. Every other kiln in the row of ten was selected as test kilns to be retrofitted with polyurethane foam while the other five kilns would serve as check kilns. The test and check kilns were selected in this manner so that a representative cross-section of the entire tobacco crop would be cured and conditioned in each kiln. This would also reduce the difference in ambient air temperature between cures in the test and check kilns.

The insulation retrofit was conducted in 1987 prior to the harvest season. The fibreboard was removed from the roofs of the five test kilns. Removing the fibreboard left a 20 mm space between the rafters and metal roof. The space was eliminated by re-nailling the metal roof to the rafters. A 25 mm thickness (RSI 1.08) of polyurethane foam was then applied to the underside of each kiln roof (see figure 2). The eave cavity (where the roof joins the walls) was also filled with polyurethane foam.

The perforated steel floors of the test kilns were removed so that the interior side of the steel bases of each kiln would be exposed. The steel bases (or C-channels) were scrapped free of rust, painted and sprayed with polyurethane foam to a thickness of 25 mm (see figure 3). The bottom lip of each C-channel, where it rests on the concrete pad, was also sealed with polyurethane foam.

Each test kiln also had a 25 mm thickness of polyurethane foam applied to the wall which separates the curing compartment from the furnace unit. The polyurethane was applied to the side of the wall that faces the furnace unit.

The last location sealed and insulated with a 25 mm thickness of polyurethane foam was the underside of the sheet metal above the furnace unit of each test kiln.

It should be noted that, since polyurethane foam is combustible, care was taken to prevent it from entering the furnace unit during application. A protective coating to prevent ultra-violet rays from breaking down the polyurethane foam was not used since the interior of the kilns would not be exposed to direct sunlight.

The cost of the polyurethane foam, including application, was \$600 per kiln and thus totalled \$3000 for the five test kilns.

MONITORING

Parameters monitored for curing and conditioning processes in the test and check kilns over 1987 and 1988 were as follows:

- i) natural gas useage;
- ii) cured tobacco weight and grade index;
- iii) general weather observations and any unusual occurrences.

EVALUATION AND RESULTS

Energy and Cost Effectiveness

A total of 78 cures were monitored over 1987 and 1988, 38 cures in the test kilns and 40 cures in the check kilns. The data collected over the two year period is summarized in appendix I and II.

Figures 4 and 5 illustrate the fuel energy useage (megajoules, MJ) per kilogram of cured tobacco for each cure in the test and check kilns during 1987 and 1988. The graphs indicate that the majority of cures in the test kilns required less energy than cures in the check kilns.

Over the 40 cures in the check kilns, 30 052.9 m³ of natural gas was consumed per 41 429 kg of cured tobacco. This equates to an energy useage of 34.6 MJ per kg of cured tobacco (assuming the energy content of natural gas is 37.7 MJ/m³). Over the 38 cures in the test kilns, 30 077.4 m³ of natural gas was consumed to cure 39 064 kg of cured tobacco. This equates to an energy useage of 29.0 MJ per kg of cured tobacco. Thus, cures in the test kilns over the two year period consumed, on average, 16% less energy than cures in the check kilns.

Curing and Conditioning Processes

The cooperator used his own judgement in selecting each kiln's curing schedule during the two years. He noted a significant improvement in the

control of air exchange rates in the test kilns as compared to the check kilns. This had no effect on the length of time to cure the tobacco in the test kilns. Over the course of the two curing seasons, the test kilns cured for 248.4 hours on average, while the check kilns cured for 248.8 hours on average.

In 1987, the time required to condition tobacco in the test and check kilns was monitored. The conditioning period averaged 15.7 hours per cure in the test kilns which was 4 hours less than the 19.7 hours per cure in the check kilns. The reduction in time required for conditioning can be attributed to the polyurethane foam's sealing characteristics which prevented leakage of moisture-laden air.

Tobacco grades from 1987 (see appendix^I), as judged by the cooperator, were similar between comparable types of tobacco cured in the test and check kilns. There does not appear to be any evidence that cured tobacco quality was improved because of improved control of air exchange rates during curing in the test kilns. Comments by the cooperator indicated that the maturity of the tobacco was the most critical factor affecting cured tobacco quality.

Tobacco quality in 1988, again judged by the cooperator, did not differ appreciably between comparable types of tobacco cured in the test and check kilns.

Cost Effectiveness

Curing in the test kilns over the two years required, on average, 0.149 m³ less natural gas per kilogram of tobacco than in the check kilns. Based on a natural gas cost of \$0.165/m³ (averaged over 1987 and 1988) and an average of 1028 kg of cured tobacco per test kiln, fuel savings amount to \$25.27 per cure. Thus, over two years of curing, the insulation retrofit resulted in fuel savings of about \$960.

The simple payback period for the insulation retrofit is as follows:

$$\begin{aligned}\text{Simple payback} &= \text{cost}/(\text{savings}/\text{year}) \\ &= \$3000/(\$480/\text{year}) \\ &= 6.25 \text{ years or about } 7 \text{ curing seasons}\end{aligned}$$

If the test kilns were fuelled by propane instead of natural gas, the annual savings would be about \$882 (assuming: propane burners operate at the same combustion efficiency as natural gas burners; 25.5 MJ/L of propane; and cost of propane \$0.205/L).

The simple payback period for the insulation retrofit is as follows:

$$\begin{aligned}\text{Simple payback} &= \text{cost}/(\text{savings}/\text{year}) \\ &= \$3000/(\$882/\text{y}) \\ &= 3.4 \text{ years or 4 curing seasons}\end{aligned}$$

CONCLUSIONS

- 1.) The insulation retrofit reduced curing fuel consumption by 16%.
- 2.) The insulation retrofit did not affect the quality of cured tobacco.
- 3.) The time required to condition tobacco in the insulated kilns was reduced by an average of 4 hours per cure as compared to the check kilns.
- 4.) Control of air exchange rates was improved by insulating specific areas of the kilns.
- 5.) The cost to retrofit each bulk kiln with polyurethane foam insulation amounted to \$600. Savings in natural gas over two curing seasons amounted to \$192 per kiln. The simple payback period is 7 curing seasons. If the bulk kilns were fuelled by propane, the simple payback period for the insulation retrofit would be 4 curing seasons.

RECOMMENDATIONS

The durability of the polyurethane foam to withstand curing/conditioning processes should continue to be monitored.

ACKNOWLEDGEMENTS

The author extends his thanks to: the cooperator, John Tamsu, for his valuable assistance in recording curing data; and the Ministry of Energy for providing partial funding of the project.

Figure 1: Fibreboard that has deteriorated and separated from the metal roof of a bulk kiln.

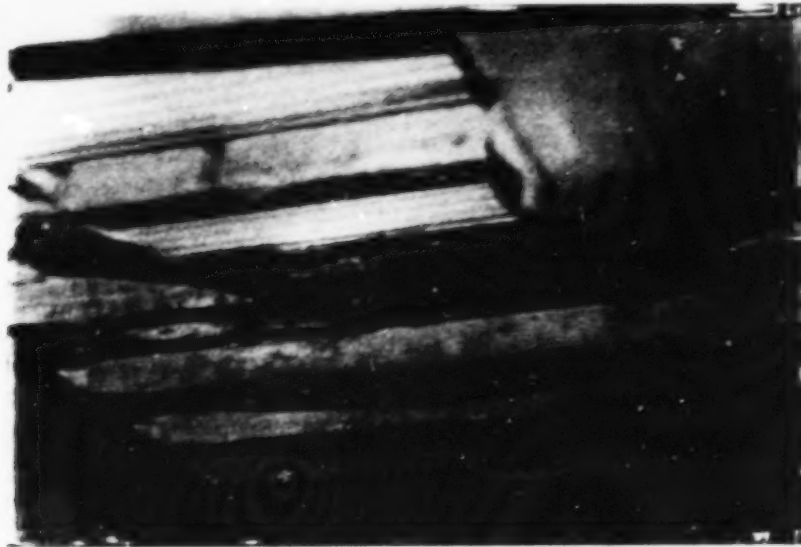


Figure 2: Polyurethane foam applied to the underside of the metal roof of a bulk kiln.

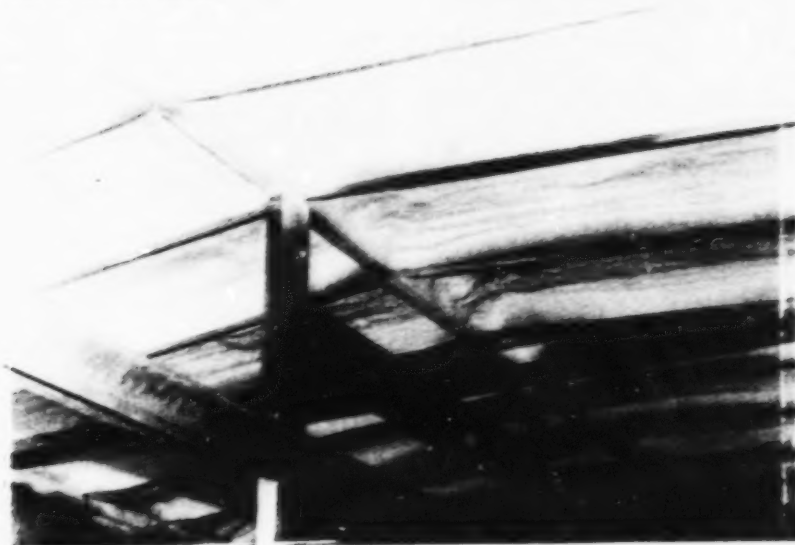


Figure 3: Polyurethane foam being applied to the steel base of a bulk kiln.



Figure 4: Energy consumption of cures in the test and check kilns during 1987

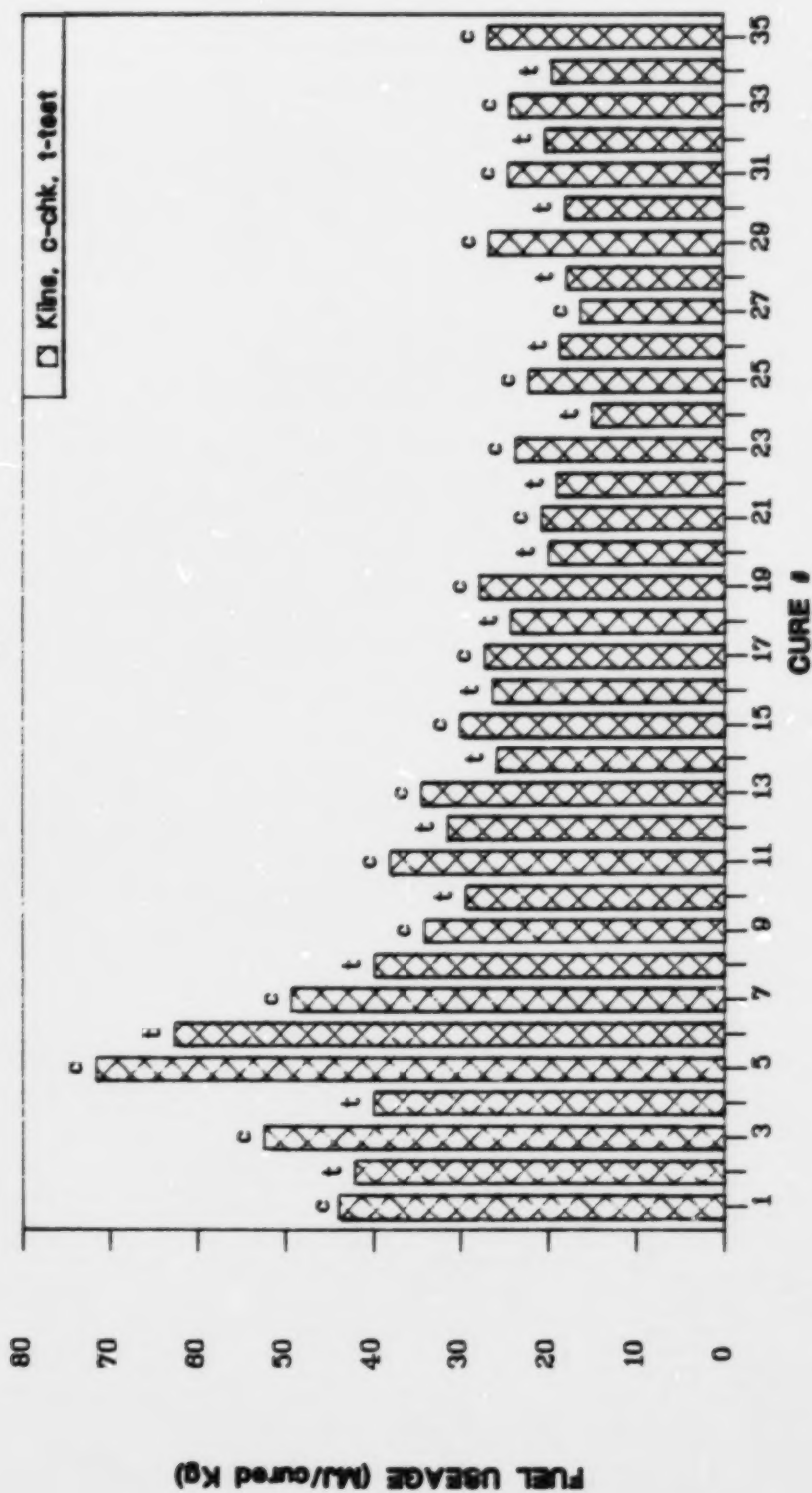
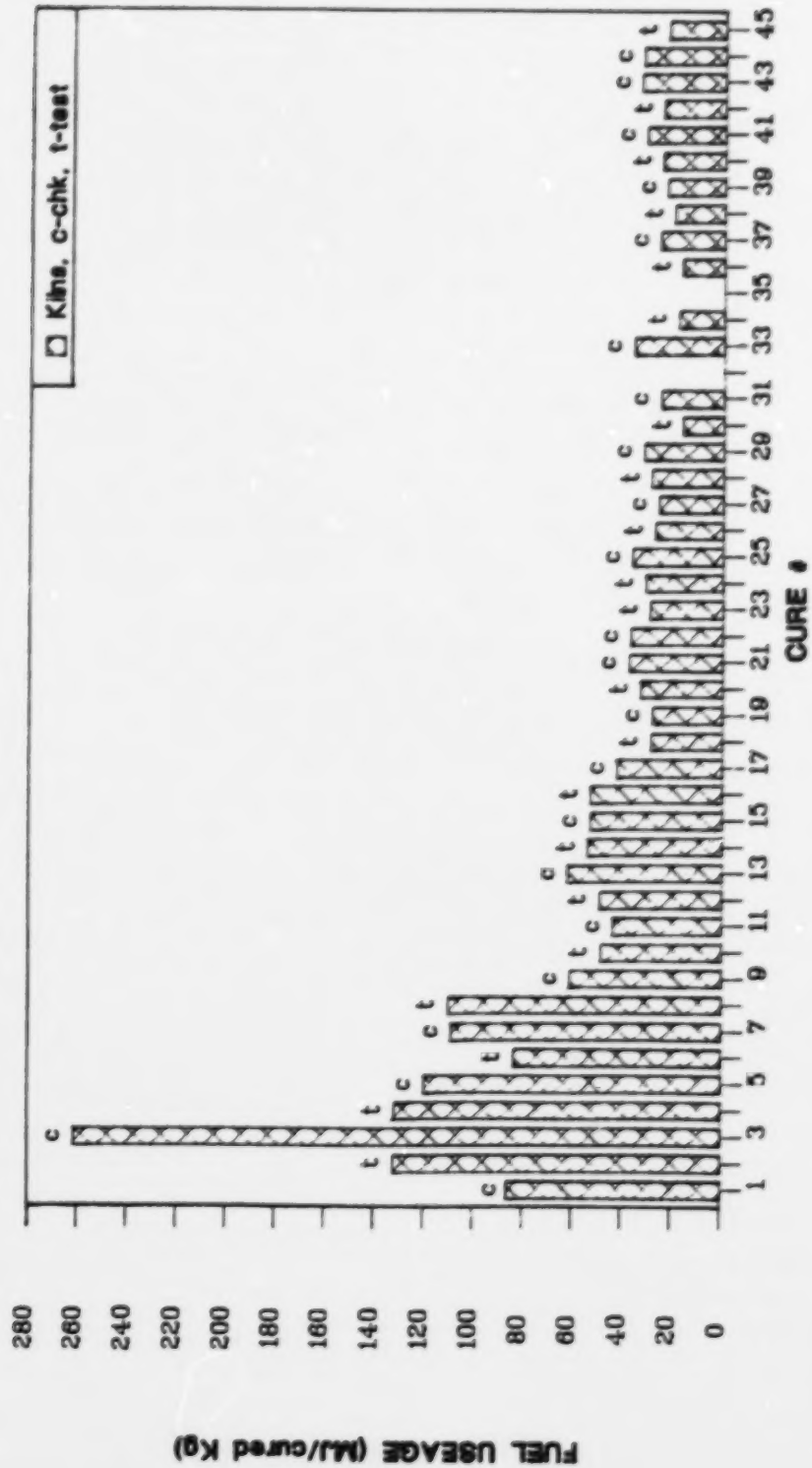


Figure 5: Energy consumption of cures in the test and check kilns during 1988



Appendix I: Curing Data 1987 Year

CURE AND KILN TYPE ¹	LEAF POSITION	CURE LENGTH (h)	GAS USEAGE (m ³)	CURED MASS (kg)	TOBACCO GRADES (majority)	ENERGY PER MASS CURED (MJ/kg)
1c	sands	215	976.2	837	XL4	44.0*
2t	sands	215	837.4	748	XL4	42.2
3c	sands	215	951.6	683	XL3	52.5
4t	sands	232	780.3	733	XL4	40.1
5c	sands	233	901.6	474	XL3	71.7
6t	sands	215	789.0	474	XL3	62.8
7c	sands	215	775.5	592	XL3	49.4
8t	sands & seconds	241	761.3	718	XL3	40.0
9c	seconds	245	884.2	971	CL2	34.3
10t	seconds	237	710.5	909	CL2	29.5
11c	seconds	240	931.0	919	CL4	38.2
12t	seconds & thirds	257	664.5	794	CF5	31.6
13c	seconds	257	1070.5	1166	CL2	34.6
14t	thirds	243	830.2	1207	CL2	25.9
15c	thirds	256	958.7	1202	CF4	30.1
16t	seconds & thirds	264	793.8	1134	CF3	26.4
17c	thirds	235	848.5	1170	CF3	27.3
18t	thirds	243	758.9	1179	CF3	24.3
19c	thirds	263	910.3	1236	CF3	27.8
20t	fourths	237	758.1	1427	BF2	20.0
21c	tips	236	882.6	1601	BF3	20.8
22t	fourths	238	710.5	1411	BF2	19.0
23c	fifths	229	935.7	1488	BF2	23.7
24t	tips	237	621.7	1565	BF3	15.0
25c	fourths	256	900.8	1529	BF3	22.2
26t	fifths	252	778.7	1581	BF2	18.6
27c	tips	251	715.3	1667	BF3	16.2
28t	fourths	255	670.9	1424	CF3	17.8
29c	seconds, thirds, fourths	257	931.7	1315	CF3	26.7
30t	tips	279	694.6	1456	BF3	18.0
31c	fourths	269	980.1	1510	CF3	24.5
32t	fifths	257	762.1	1415	CF3	20.3
33c	fourths	251	969.8	1504	CF3	24.3
34t	tips	257	752.5	1458	BF5	19.5
35c	tips	278	1011.0	1420	BF4	26.8

CURE AND KILN TYPE¹ - cure number and type of kiln, c - check, t - test

*ie. $(976.2 \text{ m}^3 \times 37.7 \text{ MJ/m}^3) / 837 \text{ kg} = 44.0 \text{ MJ/kg}$

Appendix II: Curing data 1988 year

CURE AND KILN TYPE ¹	LEAF POSITION	CURE LENGTH (h)	GAS USAGE (m ³)	CURED MASS (kg)	ENERGY PER MASS CURED (MJ/kg)
1c	sands	230	949.6	413	86.7*
2t	sands	232	836.7	238	132.5
3c	sands	230	979.6	141	261.9
4t	sands	233	883.5	252	132.2
5c	sands	227	992.5	311	120.3
6t	sands & seconds	233	1030.8	463	83.9
7c	sands & seconds	233	947.6	327	109.3
8t	sands	256	959.7	327	110.6
9c	seconds	259	1143.9	705	61.2
10t	seconds	252	969.8	748	48.9
11c	seconds	237	1007.6	866	43.9
12t	seconds	235	919.4	701	49.4
13c	seconds	233	1075.7	651	62.3
14t	seconds	244	1001.9	696	54.3
15c	seconds	257	984.0	696	53.3
16t	seconds	256	906.4	644	53.1
17c	seconds	234	847.7	751	42.6
18t	thirds	234	744.6	966	29.1
19c	thirds	239	779.3	1030	28.5
20t	thirds	240	775.8	880	33.2
21c	thirds	219	944.4	937	38.0
22c	thirds	231	970.0	980	37.3
23t	thirds & fourths	239	818.8	1048	29.5
24t	thirds	259	760.0	914	31.3
25c	thirds	263	849.7	871	36.8
26t	fourths	256	799.7	1093	27.6
27c	fourths	269	761.5	1104	26.0
28t	fourths	273	819.4	1066	29.0
29c	fourths	277	996.7	1168	32.2
30t	tips	259	585.7	1340	16.5
31c	undertips	247	837.8	1238	25.5
33c	fifths	257	1186.9	1234	36.3
34t	fifths	241	638.0	1297	18.5
36t	tips	256	597.0	1322	17.0
37c	tips	255	804.7	1170	25.9
38t	tips	236	639.8	1204	20.0
39c	fifths	266	856.3	1397	23.1
40t	fifths	264	845.6	1277	25.0
41c	fifths	295	1158.3	1383	31.6
42t	undertips & tips	300	957.2	1458	24.8
43c	tips	291	1177.0	1318	33.7
44c	undertips & tips	286	1267.0	1454	32.9
45t	undertips & tips	297	912.6	1497	23.0

CURE AND KILN TYPE¹ - cure number and type of kiln, c - check, t - test*ie. $(949.6 \text{ m}^3 \times 37.7 \text{ MJ/m}^3)/413 \text{ kg} = 86.7 \text{ MJ/kg}$